PRELIMINARY

U.S. COMMAND AND DATA HANDLING (C&DH) SYSTEM

1.1   COMMAND AND DATA HANDLING

The Command and Data Handling (C&DH) function consists of hardware and software required to communicate, command, and control all Station systems, subsystems, and payloads. The C&DH architecture contains dual redundant (1553B) control buses provided by the C&C MDMs for command, control, and data distribution. Payload local buses are connected to the control buses via Payload MDMs for command, control, and data distribution to the lower level payload processors and payload support equipment (i.e., Automated Payload Switch (APS) and Payload Ethernet Hub/Gateway (PEHG)). Eight High Rate Data Links (HRDL) are provided for payload complement utilization for passing data to the Communication and Tracking (C&T) system for telemetering to the ground. High rate payload-to-payload communications may be accomplished through use of the HRDLs. Multiple payload to payload communications within the U.S. Lab may be accomplished using the PEHG.

C&DH provides several services for payloads, particularly in the area of command and control. These services include but are not limited to payload displays and controls, data transfer, health and status monitoring, automated procedure execution, and caution and warning detection and annunciation.

Operations of the Station and payloads are controlled via the flight crew, mission and payload controller, automated and interactive processes. C&DH command and control supports both manual and automated control of the Space Station for all nominal and contingency conditions. Payload commands may be issued from automated procedures, Payload Executive Software (PES), or uplinked from the ground. All nominal operations can be manually controlled from the ground or the on-board Portable Computer System (PCS). Procedures are automated where possible to relieve the crew workload and the need to operate manually during normal communication outages.

1.1.1   C&DH Payload Support Architecture

The Payload MDM provides services to support U.S./CSA payloads located in the U.S. Lab, Centrifuge Accommodations Module (CAM), Japanese Experiment Module (JEM), and Columbus Orbital Facility (COF). The Payload MDM also provides services to support U.S./CSA attached and EXPRESS Pallet payloads. A diagram of the payload support architecture is shown in Figure 1-1. The Payload MDM provides the overall command and control functions for the payload complement. Other functions include gathering and forwarding payload complement safety data to the C&C MDM; distribution of commands from the ground, or on-board execution of automated procedures; sending requests (via PES services) to the C&C MDM for core resource allocation; and controlling PEHG and APS configurations. In addition, the Payload MDM provides crew interface management for the PCSs attached to the 1553B payload local buses. The mass storage on the Payload MDM provides storage of display files for the PCSs; storage of payload configuration files; and storage of Timeliner automated payload procedures.

Communication resources include high rate data routing for payload to downlink communications, medium rate routing for multiplexing medium rate telemetry data through
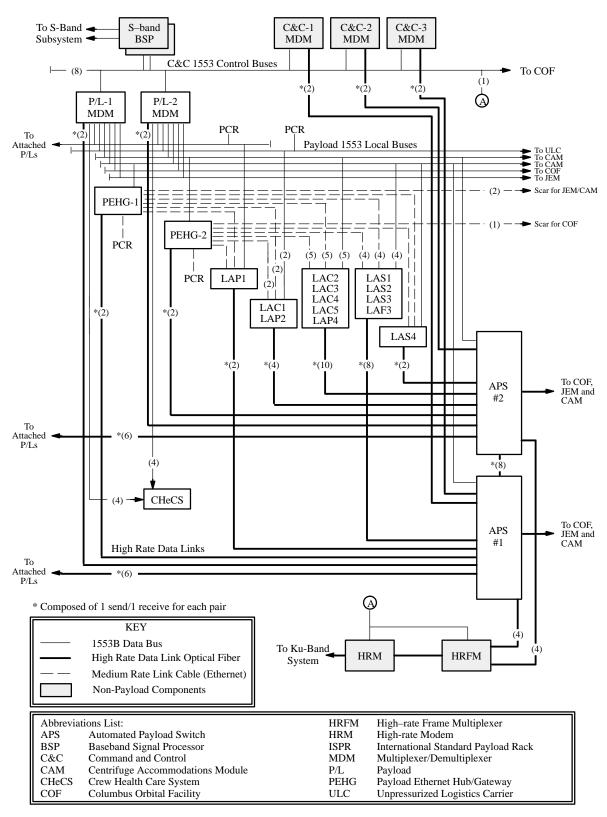
To S-Band Subsystem

S–band BSP

C&C-1 MDM

C&C-2 MDM

C&C-3 MDM

C&C 1553 Control Buses

To COF

(8)

*(2) *(2) *(2) (1)

Ⓐ

P/L-1 MDM

P/L-2 MDM

To Attached P/Ls

*(2) *(2)

PCR PCR

Payload 1553 Local Buses

To ULC
To CAM
To CAM
To COF
To JEM

(2) Scar for JEM/CAM

(1) Scar for COF

PEHG-1

PCR

PEHG-2

PCR

LAP1

(2)

(2)

(2)

(5) (5) (5) (4) (4) (4)

LAC2 LAC3 LAC4 LAC5 LAP4

LAS1 LAS2 LAS3 LAF3

LAC1 LAP2

LAS4

*(2)

*(2)

*(2) *(4) *(10) *(8) *(2)

APS #2

To COF, JEM and CAM

To Attached P/Ls

*(6)

(4)

CHeCS

(4)

*(8)

APS #1

To COF, JEM and CAM

High Rate Data Links

To Attached P/Ls

*(6)

Ⓐ

To Ku-Band System

HRM

HRFM

(4)

(4)

* Composed of 1 send/1 receive for each pair

KEY

—— 1553B Data Bus
━━ High Rate Data Link Optical Fiber
– – – Medium Rate Link Cable (Ethernet)
▢ Non-Payload Components

Abbreviations List:
APS Automated Payload Switch
BSP Baseband Signal Processor
C&C Command and Control
CAM Centrifuge Accommodations Module
CHeCS Crew Health Care System
COF Columbus Orbital Facility
HRFM High–rate Frame Multiplexer
HRM High-rate Modem
ISPR International Standard Payload Rack
MDM Multiplexer/Demultiplexer
P/L Payload
PEHG Payload Ethernet Hub/Gateway
ULC Unpressurized Logistics Carrier

FIGURE 1-1 PAYLOAD SUPPORT ARCHITECTURE

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the downlink from multiple U.S. Lab payload locations, and low rate telemetry routing for a limited set of payloads through the Payload MDM. The HDRL network provides high rate data transfer between payloads. The PEHG provides payload to payload communications capability for U.S./CSA payloads located in the U.S. Lab.

1.1.1.1 Payload MDM

The Payload MDM provides the centralized U.S. payload complement command, control, and monitoring functions implemented by the PES resident in the Payload MDM. The Payload MDM provides six dual redundant 1553B payload local buses for command /data distribution to (and data gathering from) the devices and payloads attached to the 1553B payload local buses. The Payload MDM also provides an additional four 1553B buses (a total of 10 1553B buses) for command/data distribution to (and data gathering from) Crew Health Care System (CHeCS) devices.

The 1553B payload local buses provide an interface to U.S./CSA payload locations in the U.S. Lab, CAM, JEM, and COF as well as the U.S./CSA external payload locations (i.e., attached payloads, EXPRESS Pallet Payloads). The 1553B payload local buses provide the payloads with commands and data from on-board automated payload procedures, PCSs, the ground, and ancillary data distribution (which includes time reference data, core system resource data, payload data, etc.). Payloads send their payload health and status data, payload safety data, and low rate payload telemetry data through the 1553B payload local bus to the Payload MDM. Also, payloads may request core system resources via Timeliner procedures (PES Procedure Execution Service or PES Limit Exception Service). A PCS may connect to the Payload 1553B local bus for command/monitoring of payload and system operations. Also, PCS interfaces are provided for connection to the PEHGs for higher rate operations of those U.S. Lab payloads connected to this medium.

1.1.1.1.1 Payload Executive Software

PES provides monitoring, control, and coordination of U.S./CSA payload activities on the ISS. PES is configuration table driven. These configuration tables provide operational data to PES services and utilities to support payload operations. Modification of these configuration tables are modified as the ISS payload complement changes.

There are three basic types of payload interface configurations that PES supports. A single payload rack, a multiple rack payload, and a multiple payload rack. In the case of multiple payload rack, the Remote Terminal (RT) (i.e., rack controller) is responsible for collecting and distributing all data from/to the payloads within the rack. The payload processor (which is considered a RT to PES) in a single payload rack or multiple rack payload would be responsible for collecting and distributing all data from/to the rack.

The following describes the payload services provided by PES to provide the User with a mechanism for obtaining or sending data/commands to the payloads. Payload services are available to the Users as scheduled during the pre-increment planning process. The interfaces to PES are through the C&C MDM on the system side of the Payload MDM and the payload local buses on the payload side. The payload local buses on the lower side connect to the PCS, APS, PEHG, and payloads.

1.1.1.1.1.1 Health and Status Service

Payload health and status data is the set of flight information required by the Payload Operations Integration Center (POIC) to support real-time operations and analysis. It

includes status parameters from the payloads and any on-board systems and subsystems for which the POIC is responsible. The payload health and status data is required by the POIC to monitor and manage payload operations, and is available to the payload user upon its request.

Payload safety data is the set of safety-related flight data defined by the Mission Control Center-Houston (MCC–H)/POIC and required to support real-time operations and analysis. It is processed and monitored independent of the payload health and status data.

PES processes on-orbit payload operations health and status, and safety data. PES assembles a data stream of payload specific health and status to the POIC via the Ku-band. The Consultative Committee for Space Data Systems (CCSDS) downlink packet is created by PES from data (with a CCSDS header) provided by the payload via the RT. The downlink packets are sent to the APS via the HRDL for downlink. This function supports payloads connected to the payload local 1553B bus. The payload safety data is sent to the C&C MDM for inclusion in the S-band downlink. The payload health and status, and safety data is received by PES via the payload local 1553B bus. PES also utilizes payload health and status for exception monitoring, sending parameters to the PCS for crew display, to support automated procedure execution, and to support the provision of ancillary data.

Figure 1-2 illustrates the health and status data structure collected from n number of
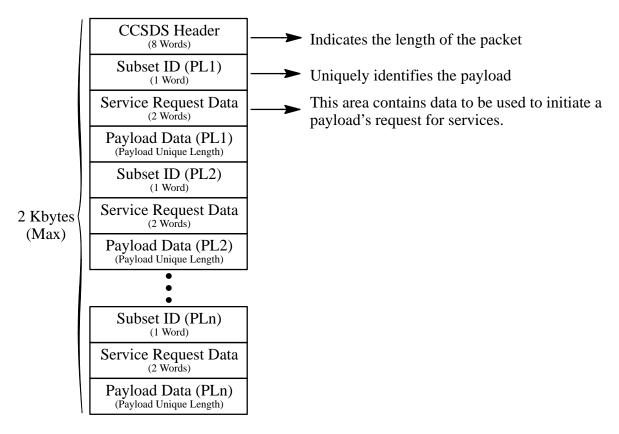

FIGURE 1-2 ISPR HEALTH AND STATUS STRUCTURE

payloads located within a single ISPR. The subset ID defines a particular payload's data. PES utilizes the subset ID to identify the length of the data and the storage area for the data.

To request a PES service (i.e., start and stop ancillary data service and low rate telemetry service, file requests, and procedure requests), the payload must place the appropriate request structure in the PES specific data location in the payload's health and status. Remaining bits after the request structure must be filled with zeros (0).

For PES to begin collecting payload health and status and safety data, a Payload Startup Notification Command must be received by PES. Prior to PES receiving the command, the payload must be activated. For PES to cease collecting payload health and status and safety data, a Payload Shutdown Notification Command must be received by PES. These commands can be generated from the crew, ground, or Timeliner. PES collects a payload's health and status and safety data at either a 0.1 or 1.0 Hz rate on a per payload basis as defined in the increment–specific configuration tables.

The method of the payload RT for providing health and status and safety data follows:

A.   Package the health and status and safety data from the RT into one CCSDS packet along with the subset IDs used to delineate the payload's data within the packet.

B.   Once the health and status and safety data has been packaged, place the RT's health and status data in the buffer associated with the health and status subaddress.

C.   Maintain the buffer for health and status subaddress by setting the "busy bit" in the 1553 status word until the health and status data has been collected by the RT and placed in the appropriate subaddress.

1.1.1.1.1.2   *Procedure Execution Service*

This capability, in conjunction with Timeliner, provides an on-orbit configurable capability to control payload operations based on command input or payload status feedback. This service is activated when a Timeliner Command is generated from the crew (via PCS), ground, or upon request from the payload. Upon receipt of a request, the Procedure Execution Service issues a command to the Timeliner Executor Identifying the User Interface Language (UIL) Bundle, Sequence, and action specified by the request. Once the bundle has been installed via an Install Bundle request, a payload can control the execution of the procedure by placing the Procedure Execution Request structure (illustrated in Table 1-II) in the PES specific data location in the payload's health and status. A Request Response is provided to a payload indicating the validity of a request. The format of a Request Response is illustrated in Figure 1-3. A Procedure Execution request is invalid if there is no sequence associated with the Sequence Identifier provide in the request. A Procedure Execution command/request is unauthorized if the request (Start/Stop/Resume) does not correspond with authorization data located in PES increment–specific configuration tables.

1.1.1.1.1.3   *Mass Storage Device (MSD) Service*

The purpose of the MSD service is two-fold. First, this capability provides a means by which payload applications can access data on the payload MSD. This functionality limits access by payload applications based on authorization data generated by the POIC. This authorization data specifies access privileges of payload applications for individual payload
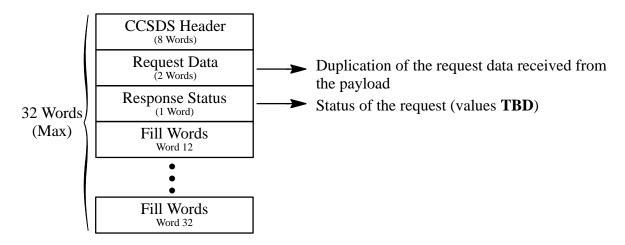
FIGURE 1-3 REQUEST RESPONSE MESSAGE STRUCTURE

MSD files. To manage the files, the payload must place the File Request Structure (illustrated in Table 1-II) in the PES specific data location in the payload's health and status. A Request Response is provided to a payload only in the event that an error has occurred. The format of a Request Response is illustrated in Figure 1-3.

Second, this capability provides the POIC a means to manage files on the payload MSD. PES may downlink data from identified payload MSD files via Ku-band telemetry upon command. PES also responds to commands to delete files from the payload MSD.

1.1.1.1.1.4   Ancillary Data Service

Ancillary data is a selected subset of core system data and other onboard generated data, including payload generated data, required to support experiment/payload analysis by Users, for use by onboard payloads during operation, and for operation of onboard payloads by the crew and ground controllers. Ancillary data describes the flight environment in which the payload is operated and includes information such as temperatures, state vectors, Station configuration, and microgravity constants. Table 1-I provides a representative list of possible ancillary data types.

PES provides ancillary data to the payload based on ancillary data sets predefined by the POIC in conjunction with the user. A payload may request PES to provide ancillary data as a one–shot or on a cyclic basis (0.1 or 1.0 Hz rate) on a per payload basis based upon the selection of the predefined ancillary data set(s). PES accepts commands from the crew, ground, or Timeliner to initiate and terminate the cyclic downlink of ancillary data to the payload, in CCSDS packet format. Upon receiving a Tier I command, PES will issue a Request Response to the payload notifying the payload to expect an ancillary data set.

This service may be activated for a particular payload via the Start Ancillary Data Service Request. The service is terminated via a Stop Ancillary Data Service Request. To receive or terminate ancillary data, the payload must place the appropriate ancillary data service request structure in the PES specific data location in the payload's health and status. The structure of these request is illustrated in Table 1-II. A Request Response is provided to

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TABLE 1-I ANCILLARY DATA TYPES (EXAMPLES)	
SYSTEM	PARAMETERS
Environmental Control and Life Support System (ECLSS)	Internal Pressure Partial Pressures, O_2, CO_2, N_2 Atmosphere Composition Relative Humidity Chemical Contaminants Internal Temperatures Smoke Detection Flame Detection Avionic Air Distribution/Temperature Radioactive Doses & Instantaneous Rates
VIDEO CONFIGURATION	Camera Status Video Switch Configuration Recorder Status Video Frame Rates Single Frame Images
Communication and Tracking	Bandwidth Utilization status Orbital Replacement Unit (ORU) Status and Performance/failures High Rate Link Utilization Status
THERMAL	Coolant Inlet Temperatures Coolant Exhaust Temperatures Flow Rate Low/Moderate Temp Loop Temperature In Low/Moderate Temp Loop Temperature Out
ELECTRICAL	Rack Current Usage Supply Voltage RPCM On/Off Power Status
VACUUM SYSTEM	Motor Operated Valve Open/Closed Position Manifold Pressures
RATES	Body Rate X-Axis, Y-Axis, Z-Axis
LVLH ATTITUDE M-50	Quaternion (1-4)
STATE VECTOR	X, Y, Z-Comp of Current Position Vector X, Y, Z-Comp of Current Velocity Vector
MISCELLANEOUS	Greenwich Mean Time (GMT) Mission Elapsed Time Station Modes Acceleration Levels Vibrations System Pumps Crew Operations/Activity Sun Vector

a payload only in the event that an error has occurred. The format of a Request Response is illustrated in Figure 1-3.

Figure 1-4 illustrates the message format for Ancillary Data which is sent by PES to a payload. A payload can request one data set per command request and PES sends only one data set to a payload for any given request. A data set is limited to 23 words (exclusive of the CCSDS header). There is a maximum of 100 data sets allowable for any payload complement.
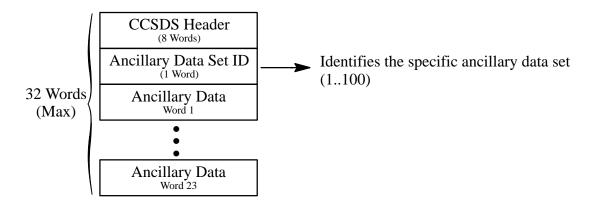

FIGURE 1-4 ANCILLARY DATA TO REMOTE TERMINAL

1.1.1.1.1.5   Low–Rate Telemetry Service

PES supports the low–rate downlink of payload data. PES accepts data from payloads and telemeters the data to the ground via the high-rate data link to the APS. Figure 1-5 illustrates the data structure of low–rate telemetry data collected from n number of payloads located within a single ISPR.

This service may be activated for a particular payload via the Start Low Rate Telemetry Request. The service is terminated via a Stop Low Rate Telemetry Request. To receive or terminate low-rate data, the payload must place the appropriate low-rate telemetry request structure in the PES specific data location in the payload's health and status. The structure of this request is illustrated in Table 1-II. A Request Response is provided to a payload only in the event that an error has occurred. The format of a Request Response is illustrated in Figure 1-3. PES accepts commands from crew, ground, Timeliner, or payloads to initiate and terminate low–rate service. Upon receiving a Tier I command, PES will issue a Request Response to the payload notifying the payload to initiate or terminate low–rate provision. PES collects a payload's low–rate science data at either a 0.1 or 1.0 Hz rate on a per payload basis.

A Start Low Rate Telemetry Request is invalid if the requesting payload is currently being provided the Low Rate Telemetry Service. A Stop Low Rate Telemetry Request is invalid if the requesting payload is currently not being provided with Low Rate Telemetry Service.

Upon receipt of a valid Start Low Rate Telemetry Request from a payload, the Low Rate Telemetry Service starts to downlink data for a specified payload. A Request Response
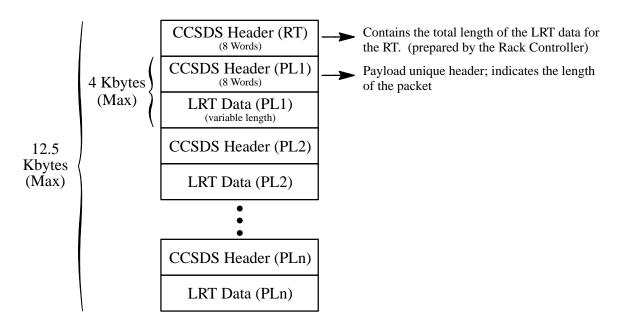
```
                          ┌─────────────────────────┐
                          │   CCSDS Header (RT)      │ ──→  Contains the total length of the LRT data for
                          │       (8 Words)          │       the RT.  (prepared by the Rack Controller)
                          ├─────────────────────────┤
            4 Kbytes  ⎧   │   CCSDS Header (PL1)     │ ──→  Payload unique header; indicates the length
             (Max)    ⎨   │       (8 Words)          │       of the packet
                      ⎩   ├─────────────────────────┤
                          │    LRT Data (PL1)        │
   12.5                   │   (variable length)      │
   Kbytes                 ├─────────────────────────┤
   (Max)                  │   CCSDS Header (PL2)     │
                          ├─────────────────────────┤
                          │    LRT Data (PL2)        │
                          └─────────────────────────┘
                                    •
                                    •
                                    •
                          ┌─────────────────────────┐
                          │   CCSDS Header (PLn)     │
                          ├─────────────────────────┤
                          │    LRT Data (PLn)        │
                          └─────────────────────────┘
```

FIGURE 1-5 ISPR RT LOW–RATE TELEMETRY STRUCTURE

is issued to the requesting payload. PES requests the payload low–rate telemetry data (in its own CCSDS formatted packet) by obtaining the contents of the low–rate telemetry RT subaddress. The data is then downlinked through the APS at the indicated telemetry downlink rate. PES supports the transfer of low–rate telemetry data up to 12.5 Kbytes from each RT. PES can only obtain four Kbytes from the low–rate telemetry RT subaddress during a single read. Therefore, if a payload's low–rate telemetry is greater that four Kbytes, each four Kbytes is required to be formatted within a CCSDS packet.

Upon receipt of a valid Stop Low Rate Telemetry Request, the Low Rate Telemetry Service assures that the downlink data is currently active for that payload and then discontinues providing the downlink data for the payload. For a valid request, a Request Response is issued to the requesting payload.

The method of the payload RT for providing low-rate telemetry data follows:

A.   Package the low-rate telemetry data from the RT into one low-rate telemetry packet with CCSDS headers used to delineate the payload's data within the packet.

B.   Place the RT's low-rate telemetry data on the low-rate telemetry subaddress with a low-rate telemetry header containing the total length of the data.

C.   Maintain the buffer for the low-rate telemetry subaddress by setting the "busy bit" in the 1553 status word until the low-rate telemetry data has been collected by the RT and placed in the appropriate subaddress.

1.1.1.1.1.6   Limit Exception Service

The Limit Exception Service monitors payload and payload support system data to detect out-of-limit conditions. A Limit Exception response consists of initiating pre-defined

TABLE 1-II REQUEST STRUCTURES		
Request Type	Structure	Description
Start Ancillary Data	Request Identifier (2 bytes) | Data Set Identifier (1 byte) | Cyclic/ Aperiodic (1 byte)	Request ID: 1 Data Set ID: Unique integer value Cyclic/Aperiodic: Indicator of whether the data set is to be transmitted cyclically or aperiodically.
Stop Ancillary Data	Request Identifier (2 bytes) | Data Set Identifier (1 byte)	Request ID: 2 Data Set ID: Unique integer value
Start High Rate Telemetry	Request Identifier (2 bytes)	Request ID: 3
Stop High Rate Telemetry	Request Identifier (2 bytes)	Request ID: 4
Read File	Request Identifier (2 bytes) | File Identifier (2 bytes)	Request ID: 16 File ID: Unique integer value relating to a file
Write File	Request Identifier (2 bytes) | File Identifier (2 bytes)	Request ID: 17 File ID: Unique Integer value relating to a file
Start Procedure Execution	Request Identifier (2 bytes) | Sequence Identifier (2 bytes)	Request ID: 18 Sequence ID: Unique Integer value relating to the sequence
Stop Procedure Execution	Request Identifier (2 bytes) | Sequence Identifier (2 bytes)	Request ID: 19 Sequence ID: Unique Integer value relating to the sequence
Resume Procedure Execution	Request Identifier (2 bytes) | Sequence Identifier (2 bytes)	Request ID: 20 Sequence ID: Unique Integer value relating to the sequence
Install Bundle	Request Identifier (2 bytes) | Bundle Identifier (2 bytes)	Request ID: 21 Bundle ID: Unique Integer value relating to the bundle

1.1.1.1.2   Payload Application Software

Payload Application Software (PAS) is payload unique software developed to perform specific data acquisition, data reduction, data processing, and data manipulation requirements for the complement of payloads on a given increment. PAS executes in the

Payload MDM (with PES) and in the PCS. PAS is provided by the program via payload developer requirements and funding.

Because of the limited memory resources and complexity of the Payload MDM, the development of PAS for the Payload MDM is expensive in both schedule and resources. The majority of PAS will be developed to execute on a PCS.

1.1.1.1.3   Payload Mass Storage

The Payload MDM provides a non-volatile MSD for storage and retrieval of Timeliner bundles, files for laptops, files for payloads, log files, PES configuration tables, etc. The MSD provides a formatted storage capacity of at least 300 MBytes.

1.1.1.1.4   Timeliner

Timeliner provides the UIL function to control payload operations via sequences and commands. UIL procedures may be operated automatically, or operated under close monitoring and control of Users.

The implementation of UIL has two parts, the Compiler and Executor. The UIL Compiler, located in the POIC, prepares procedures for execution. A "raw" script is read in as ASCII data. The statements are parsed, data and command references resolved, and error messages are issued if necessary. The output of the Compiler is a listing file, a file of executable data, and a system data reference file. The UIL "compilation unit" is known as a "bundle".

The UIL Executor, located in the Payload MDM, executes the procedure embodied in a compiled UIL script. Multiple procedures (bundles) may be executed simultaneously. Within each bundle, each sequence is treated as a logically independent "string" or "thread" of execution. The Executor reads and responds to a set of real-time commands that allow a User to control script execution, and outputs its status for use in UIL monitoring.

1.1.1.2   Portable Computer System

The PCS is a subsystem of the C&DH system that provides commanding, monitoring, and visual annunciation for crew interface to the payloads as well as the Space Station. The PCS also provides a crew interface to operate local COTS applications, such as a word processor, in a stand-alone fashion. The PCS includes peripherals (keyboard, cursor control device, display device) and a 1553B and Ethernet data interface (via the portable computer interface adapter). These components allow for the acquisition, processing and manipulation of information, and support the control, monitoring, logistics, scheduling, and other tasks or functions required for payload operations. The 1553B payload local buses provide two portable computer ports via Utility Outlet Panels (UOP). The Ethernet network provides two portable computer ports via UOPs. PCS protocol definition across the 1553B bus and Ethernet is defined in the ISS Prime Contractor Software Interface Control Document (ICD), Part 1, Station Management and Control to International Space Station Alpha (ISSA), SSP 41175.

Displays are built using the Sammi display development tool (format editor). The Sammi runtime environment transmits, receives, and displays data from the payload local

buses or Ethernet. Displays provide the capability to monitor payload health and status data, system data, caution & warning and fault summary, and time. Displays also provide the capability to command a payload. All payload displays are required to comply with the display format requirements given in SSP 50005.

Sammi provides a standard set of visual components that are displayed on the screen, including gauges, bar graphs, push buttons, menus, windows, and a wide array of other graphical devices. The Sammi generated displays can be moved, resized, or overlapped in any manner desired. The display begins receiving data as soon as it is added to the PCS screen, and it quits receiving data as soon as it is removed.

1.1.1.3   Payload Ethernet Hub/Gateway

The PEHG provides data packet transfer between User payloads, laptops, and a telemetry forwarding capability. The PEHG provides this signal regeneration capability for a Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Institute of Electrical and Electronic Engineers (IEEE) 802.3 (Ethernet) network. This network is implemented in the U.S. Lab using twisted-shielded pair cables configured in a hub-and-spoke topology, and operates at a data rate of 10 Mbps. The PEHG also provides a telemetry forwarding capability for incoming packets with specific destination addresses. This telemetry is forwarded via a HRDL to the HRFM through an APS. The PEHG is controlled via instructions from the Payload MDM received over the 1553B bus.

The PEHG provides a central hub or repeater mechanism for distributing incoming IEEE 802.3 packets (and collisions) to all active output ports per the IEEE 802.3 protocol of a 10 Mbps Ethernet (i.e., 10BASE-T) network. Ethernet is based on a bus topology that utilizes a CSMA/CD technology.

The IEEE 802.3 CSMA/CD protocol defines how a payload User (or node) may gain access to the network. The node first monitors the media to ensure that no transmissions are in progress (Carrier Sense). The node may then decide to transmit simultaneously, then a collision will occur. All nodes must be able to detect this condition (Collision Detection), stop their transmissions, and retry after a random period of time.

The 10BASE-T networks require central hubs or repeaters to extend the signals around the network. The IEEE 802.3 standard defines the basic, mandatory, and optional requirements to ensure interoperability for 10BASE-T repeaters.

The payload Users may interface to the PEHG's 10BASE-T ports. The PEHG may also be interconnected in order to extend the physical system topology, thereby providing for the coupling of two more network segments into a common collision domain.

The PEHG also provides a simple telemetry forwarding capability for incoming packets with specific destination addresses. The gateway function checks the destination addresses of all incoming IEEE 802.3 packets, remove the IEEE 802.3 packet overhead from specific packets, and immediately transmit the unwrapped User data over the PEHG's optical port. The gateway function provides a IEEE 802.3 standard "flow control" broadcast function which is sent to the active Users in order to control the throughput level of any high-level traffic. The PEHG output rate is configured by the Payload MDM to match the HRFM input port data rates. Also the gateway function provides a 64 Kbyte buffer along

with an IEEE 802.3 standard "buffer full" broadcast function which is sent to all active Users when the buffer is filled with data packets being transmitted.

The PEHG is controlled via instructions received over its dual-redundant 1553B interface. The PEHG accepts commands regarding initialization and shutdown, gateway card enable and disable, individual transceiver enable and disable, PEHG status, built-in self-test, counter status, and other operating parameters.

1.1.1.4 Automated Payload Switch

The APS provides remote switching of high rate data between any one of its 44 fiber optic inputs to any one of its 36 fiber optic outputs (up to 20 simultaneous connections may be supported.) The U.S. Lab provides two APSs, each connecting to approximately half of the ISPR and attached payload locations onboard the ISS. The APSs are cross strapped so payloads on one APS can communicate (via HRDL connections between the APSs) to payloads connected to the other APS. The APSs also have four connections each to the Ku band telemetry system (for a total of eight connections). The switching configuration is controlled via instructions from the Payload MDM received over the 1553B bus.

1.1.1.5 Payload Data Interfaces

The C&DH data interfaces provided to a U.S. Lab ISPR location include the MIL-STD-1553B, HRDL, and Medium Rate Data Link (MRDL). A summary of the data interface characteristics is given in Table 1-III.

TABLE 1-III C&DH PAYLOAD INTERFACE CHARACTERISTICS		
INTERFACE	PARAMETER	SPECIFICATION
1553B	Data Rate	1 Mbps *
	Medium	MIL–STD–1553B Twisted–Shielded Pair
High Rate Data Link	Data Rate	Up to 100 Mbps *
	Medium	Fiber Optics PHY ISO 9314–1
Medium Rate Data Link	Data Rate	10 Mbps *
	Medium	Ethernet Twisted–Shielded Pair

* Aggregate rate, not individual payload rate

Payloads may use any chipset that meets the C&DH interfaces. Chipsets currently being used on Space Station are defined in SSP 30423, Rev. D, 4 May 1992. Payloads are not required to use the chipsets listed in SSP 30423.

1.1.1.5.1   Packet

ISS requires that all communication with the ground (forward and return) and on-board with C&DH components be in the form of CCSDS packets or CCSDS bitstream data (HRDL only) (as specified in the Consultative Committee for Space Data Systems Architectural Recommendation, Blue Book, CCSDS 701-0-B-1). However, a CCSDS packet is not required for payload to payload communication via the MRDL or the HRDL.

MSFC-STD-1274A defines the fields of the primary header and explains how to populate these fields. The APID is assigned by the program. The User data field contains parameters/samples (any analog, discrete, or character value that is polled and telemetered) as defined by the payload. MSFC-STD-1274A defines the types of sampling allowed and the arrangement of samples in a data stream.

1.1.1.5.2   Program Unique Identifiers

A signal (synonymous with parameters or samples as defined above) is defined as data needed or provided by the flight crew; ground crew; payload hardware elements; payload Firmware Controllers; payload provided laptops; or payload processor application and system services software to monitor, control, or define its state. ISS signals require a 13 character Signal Program Unique Identifier (PUI) as defined in section 3.3.1, Program Unique Identifiers, of the Prime Contractor Software Standards and Procedures Specification, D684-10056-1. The program requires the participation and support of payload developers during the PUI assignment process.

1.1.1.5.3   Payload 1553B Local Bus

The Payload 1553B local bus consists of the electrical twisted-shielded pair cabling and connectors interconnecting the Payload MDM to its RTs (i.e., ISPR location). The Payload 1553B local bus provides the JEM ISPRs, U.S. Lab ISPRs, COF ISPRs, CAM ISPRs, and external payload locations with a command/control and data distribution interface as well as a limited low rate telemetry interface for U.S./CSA payloads. The Payload 1553B local bus also provides data transfer; commanding; re-configuration; and timing distribution.

Time is broadcast from the Payload MDM via the payload 1553B local bus to its RTs using a RT subaddress of "31". The time format is illustrated in Table 1-IV. More information on timing distribution is defined in PG-3 Software ICD, Part 1, Payload MDM to ISS, SW683-70833-1.

A RT can communicate with the Payload MDM via the Payload 1553B bus by meeting the electrical, signal, and protocol requirements of MIL-STD-1553B. All communication between the RTs and the Payload MDM are via CCSDS packets utilizing the 1553B protocol.

1.1.1.5.3.1   Communication Format on the Payload 1553B Bus

The PES communicates with RTs located on the local bus through the use of subaddresses that have been allocated to particular PES functions. The software that provides the RT interface for the payload is required to package data to be sent to the PES in

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\multicolumn{5}{c}{TABLE 1-IV LOCAL BUS TIME MESSAGE}
Word #	Description	Function	Range	Position
---	---	---	---	---
CW	1553B Command Word			
1	CCSDS Preamble	Preamble field "01010000"		0-7
	Time code - Year High	Most significant 8 bits of BCD year field	19-20	8-15
2	Time code - Year Low	Least significant 8 bits of BCD year field	0-99	0-7
	Time code - Month	BCD Month field	1-12	8-15
3	Time code - Day of Month	BCD Day of Month field	1-31	0-7
	Time code - Hour	BCD Hour field	0-23	8-15
4	Time code - Minute	BCD Minute field	0-59	0-7
	Time code - Second	BCD Second field	0-59	8-15
5	Spare		0	0-11
	Binary Subseconds High	Most significant 4 bits	0-15	12-15
6	Binary Subseconds Low	Least significant 16 bits (1 bit = 1 μsec)	0-65535	0-15
7	UTC Conversion Parameters	UTC leap seconds (BCD)	0-9999	0-15
8	Non-CCSDS Seconds/Subseconds	(Ones portion of BCD Second field + binary subseconds) converted to binary count rounded to nearest 256 μsec (LSB = 256 μsec)	0-65535	0-15

the correct format and place it on the correct subaddress for acquisition by PES. Also, the RT interface software for the payload is required to retrieve data sent out by the PES from the correct subaddress and distribute it to the payload. Subaddress assignments are shown in Table 1-V.

TABLE 1-V SUBADDRESS ASSIGNMENTS
DATA BEING TRANSMITTED TO THE PAYLOAD MDM FROM A PAYLOAD
Subaddress # 9	Health and Status Data
Subaddress # 8	Science
Subaddress # 17–25	Files
DATA BEING RECEIVED BY A PAYLOAD FROM THE PAYLOAD MDM
Subaddress # 7	Ancillary Data
Subaddress # 8, 9	Command
Subaddress # 10	Request Response
Subaddress # 15–23	Files

1.1.1.5.3.2   ISS 1553B Restrictions

ISS restricts the use of the following MIL-STD-1553B capabilities:

A.   RT-to-RT Transfers. All communication along the payload local bus is via the Payload MDM. Therefore, RT-to-RT transfers are not allowed.

B.   Transfer of Bus Controller (BC) capabilities. The Payload MDM is the sole source of communication within the C&DH payload architecture. Therefore, the Payload MDM can not transfer BC capabilities to a RT.

C.   Broadcast Status Word Response. Transmission of a status word after reception of a time broadcast is not required. If multiple RTs simultaneously transmit their status responses, a bus "crash" could occur.

1.1.1.5.3.3   Electrical Characteristics

The electrical characteristics of the MIL-STD-1553B Bus Media is as specified in MIL-STD-1553B.

1.1.1.5.4   Medium Rate Data Link

Two IEEE 802.3, 10Base–T compliant Local Area Networks (LAN) are provided in the U.S. Lab for payload use. One LAN, the Payload to Payload LAN, is configured for multi–ISPR communications which can not be achieved with the HRDL network. The other LAN, the Payload Telemetry LAN, is configured to provide a medium rate telemetry (less that 10 Mbps) interface for ISPRs in the U.S. Lab. It is possible to configure either of the LANs to provide the PCS to payload, multiple payload to multiple payload and medium rate telemetry functions. This provides some capability for one LAN to serve as a backup. However, bandwidth limitations may constrain payload operations when only one LAN is performing functions of both.

No interconnection is provided between the two LANs. They are physically separated so that each LAN individually provides 10 Mbps (including communications overhead) of data transfer capability. The Ethernet bandwidth is a limited resource the use of which must be planned in order to prevent over loading.

Medium rate routing is accomplished through the PEHGs for U.S./CSA payloads in the U.S. Lab. The PEHGs provide multiplexing capability for each of up to 21 10BASE-T ports. Of the 21 ports, 1 port is an Auxiliary User Interface (AUI) used for an external transceiver. Each U.S. Lab ISPR location may generate medium rate data up to 10 Mbps for multiplexing of the data through a dedicated PEHG serial digital interface. Transmission rate, encoding, bit error rate, and other signal characteristics for incoming and outgoing IEEE 802.3 packets are specified by the IEEE 802.3 10BASE-T standard. The specific contents of the communications formats are **TBD**. The PEHG signal characteristics are indicated in Table 1-VI.

TABLE 1-VI PEHG DATA SIGNAL CHARACTERISTICS	
INTERFACE	DATA SIGNAL CHARACTERISTICS
MIL–STD–1553B	per the standard MIL–STD–1553B specification
10BASE–T ports	per IEEE 802.3, 1993 Edition
Gateway output ports	PEHG optical launched power: –14.0 dBM (decibels referred to 1 milliwatt) minimum measured optical power. Wavelength = 1310± 130 nm.

The Payload to Payload LAN may use any User defined protocol for data rates up to 10 Mbps. However, routing of telemetry data to the Ku-band HRFM requires the data to be formatted in CCSDS packets. Telemetry data that is processed by the Huntsvill Operations and Support Center (HOSC) must comply with telemetry packet structure characteristics and constraints as defined in the MSFC HOSC Telemetry Format Standard, MSFC-STD-1274A, Volume 2.

1.1.1.5.4.1   Electrical Characteristics

The electrical characteristics of the Medium Rate Link Media is as specified in ISO/IEC 8802-3 (IEEE 802.3 Standards), Information technology - Local and metropolitan area networks.

1.1.1.5.5   High Rate Data Link

The HRDL network consists of two APSs and the fiber optic media required to transfer high rate data between two payloads, and for data transfer between payloads and the Communication and Tracking (C&T) Ku band telemetry system. The HRDL network also provides the capability to transfer high rate data between the Payload MDM and the Ku band system, C&C MDM and Ku band system, and between the Payload Ethernet Telemetry LAN and the Ku band system.

The ISPRs in the U.S. Lab, JEM, COF, CAM, and attached payloads are provided with two connections each to the HRDL network (a transmit fiber and a receive fiber). The HRDL interface is provided as an option to meet unique payload data transfer requirements.

The HRDLs are capable of transporting up to 100 Mbps of data. The APS switches are configured by the Payload MDM to route User data. Routing of high rate telemetry data to the Ku-band HRFM requires the data to be formatted in CCSDS packets or CCSDS bitstream and transferred in a manner which meets the HRFM digital input specifications. High rate telemetry data that is processed by the HOSC must comply with telemetry packet structure characteristics and constraints as defined in the MSFC HOSC Telemetry Format Standard, MSFC-STD-1274A, Volume 2.

Payloads must comply with the 4B/5B encoding, command symbols, and data patterns for connection to the HRDLs as specified in ISO 9314-1. The 4B/5B encoding can transmit and receive optical data over a pair of HRDLs (one configured as transmit, the other configured to receive). This interface can provide transfer of CCSDS packet or bitstream data to the C&T system.

Bitstream data formatting consists of the payload/data source providing an undelimited stream of digital data via the HRDL. There are no start or stop delimiters which is the case for packet data. Data is 4B/5B encoded and is transferred at a data rate of 100 Mbps.

The only source of bitstream data to the Ku–band downlink are the HRDLs. The HRFM receives this stream of digital data and encapsulates this data into Bitstream Protocol Data Units (BCDU). The BPDUs are then encapsulated into Virtual Channel Data Units (VCDU) similar to how packets are encapsulated by the HRFM. The Virtual Channel Identifier (VCID) field within the VCDU provides the reference to the source of the bitstream data. Finally a Channel Access Data Unit (CADU) consisting of a VCDU with synchronization added is the final step in encoding the data for transfer through TDRSS. It is important to note that the individual port on the HRFM has to be configured to receive bitstream or packet data. It is not possible to send bitstream data and packet data to the same port without reconfiguration of that port.

1.1.1.5.5.1   Electrical Characteristics

The electrical characteristics of the HRDL fiber optics media are compliant with the requirements of SSQ 21654.